RHIC Pressure Rise Observation and Questions

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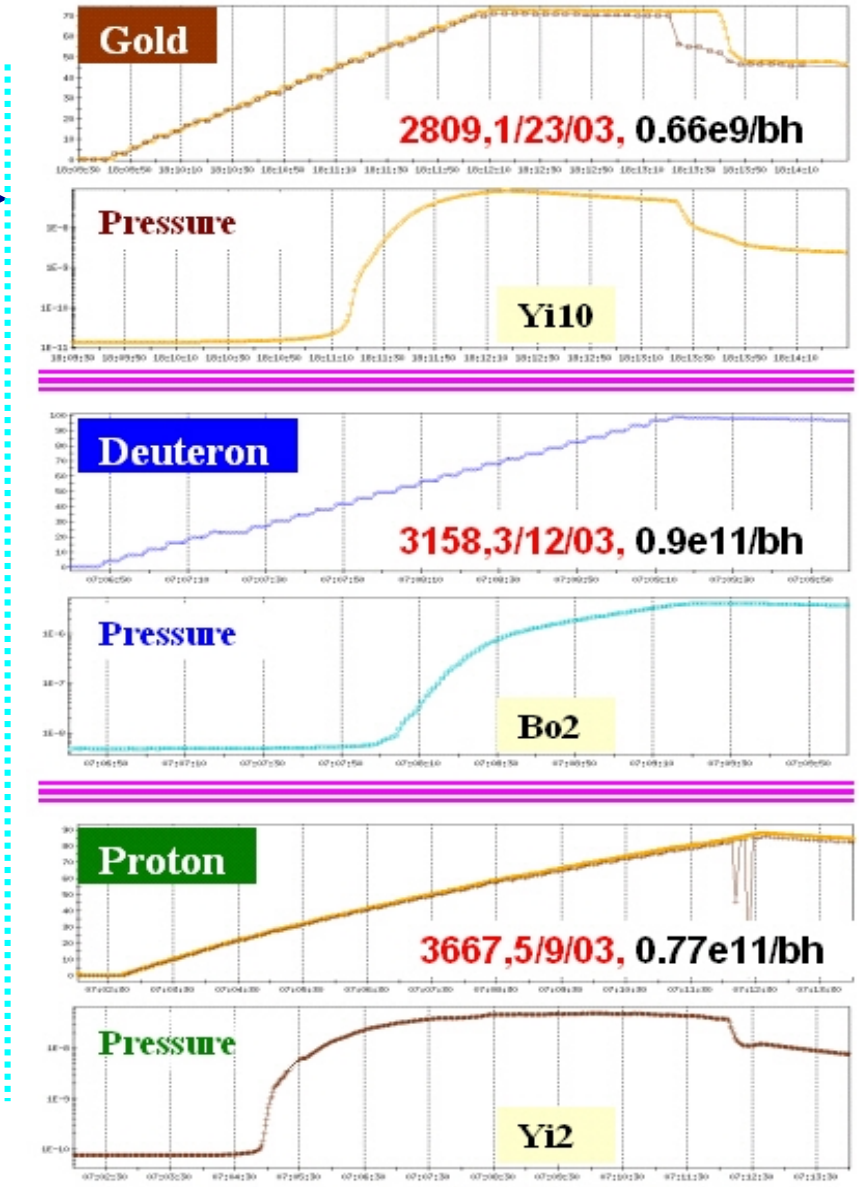
1. **RHIC injection pressure rise and electron cloud**
   - Electron cloud induced pressure rises for gold, deuteron and proton
2. **RHIC electron cloud is different from other machines**
   - RHIC EC happens at some warm pipes, for up to 216 ns bunch spacing
3. **Observation of RHIC EC induced pressure rise**
   - RHIC EC induced pressure rise - characteristics
4. **Transition pressure rise in gold and deuteron operations**
   - quasi - exponentially proportional to total beam intensity
5. **Effect of the beam halo scraping**
   - Halo scraping effect may explain most observations
6. **Questions**
   - Many questions remain
7. **Study plans**
   - Beam scraping, beta star study, NEG pipes in RHIC and Tandem

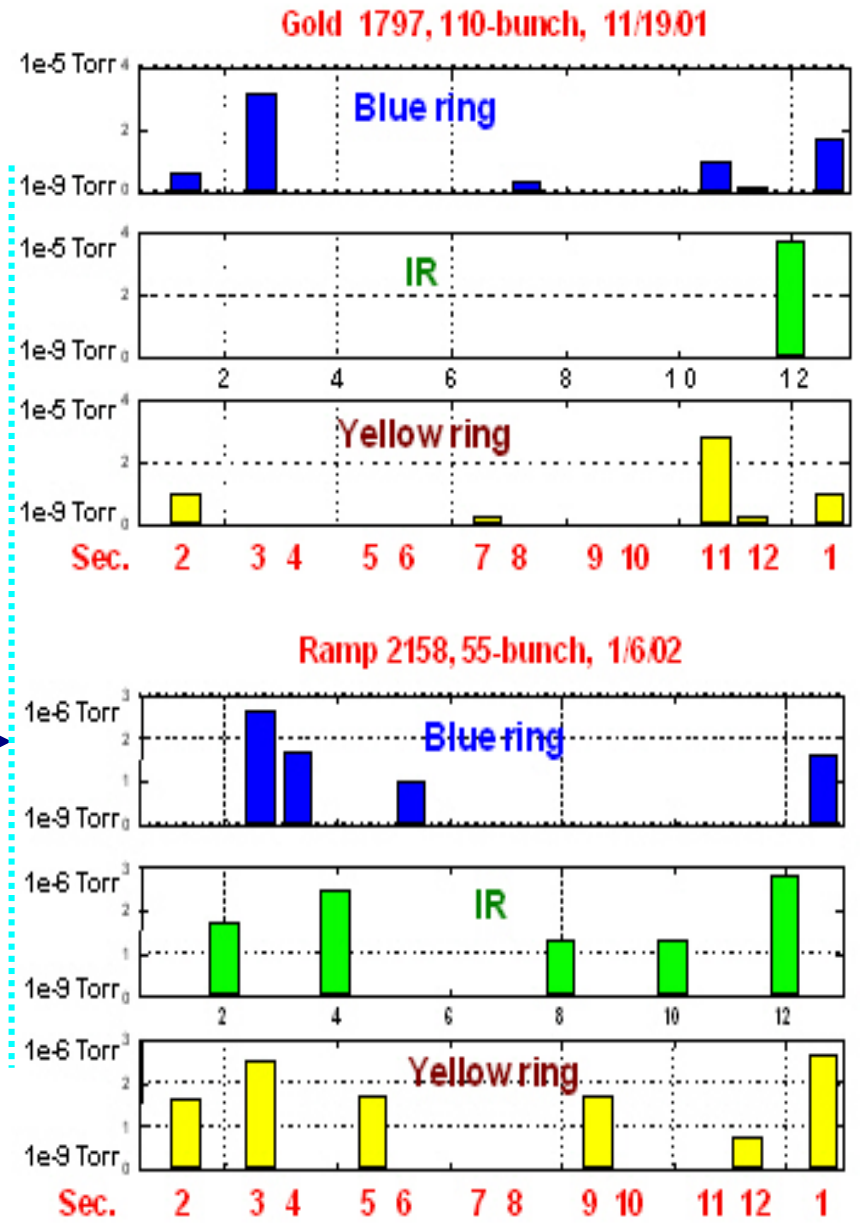
1. RHIC injection pressure rise and electron cloud

- Electron cloud induced pressure rises have been observed at the RHIC injection for gold, deuteron and proton beams.
- Signals observed by electron detectors closely related to the pressure rises.
- Pressure rise and EC are very sensitive to bunch spacing, and bunch intensity.
- At given intensity, both e-signal and pressure rise tend to saturate.
- Bunch gaps allow higher intensity.
- Beam scrubbing successfully tested, which could be ready to use in the proton operation.
- Solenoid can suppress both EC and pressure rise. No complete suppression has been achieved.



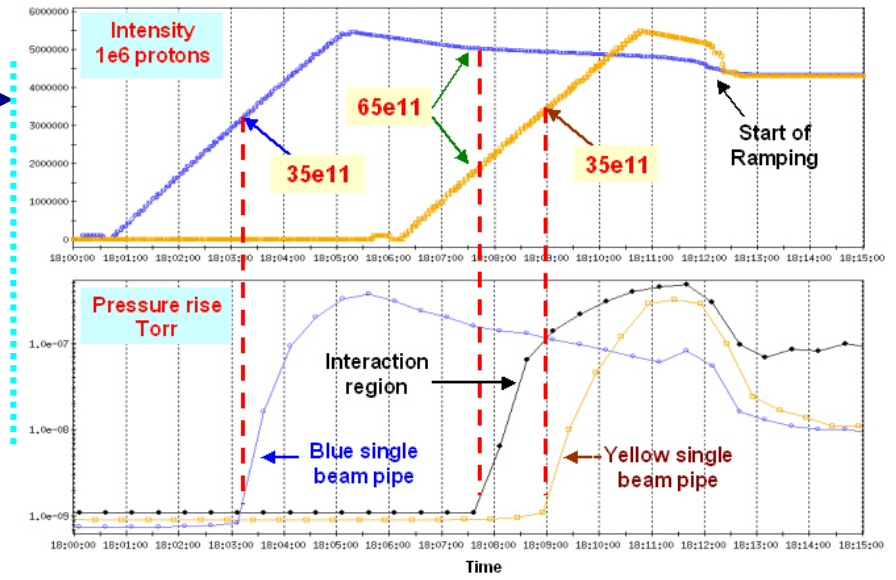
2. RHIC electron cloud is different from other machines

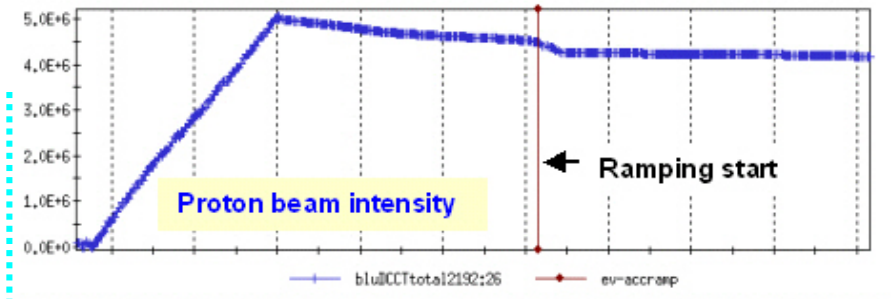
- RHIC electron cloud observed at up to 216 ns bunch spacing, compared with B- factories 4 to 8 ns, APS 20 ns, SPS 25 ns.
- EC and pressure rise observed only at warm straight sections, cold pipe (r = 3.46 cm) is supposed to have lower threshold than warm pipe (r = 6.14 cm).
- No noticeable cryogenic heat load has been reported.
- Pressure rises are non - uniformly distributed in warm sections, the locations may change.
- No significant effect of beam instability and emittance growth due to EC has been observed. Is this because of limited warm regions (700m / 3834m)?

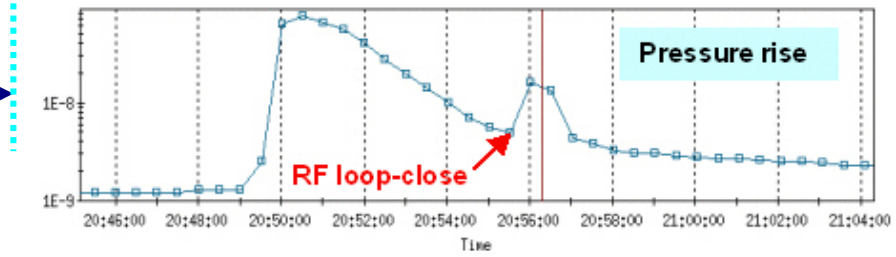


3. Observation of RHIC EC induced pressure rise

- EC threshold at Q3 - Q4 (single beam straight section) is ~ 60% of that at the interaction region. Q3 - Q4 is 34 m, IR is 20 m long. Chambers are similar.
- IR12 pressure rise was much worse than IR4. Chambers are the same, but many interruptions at IR4 (RF & instrumentation).
- Gold beam induced pressure rise is much worse than proton beam.
- $\beta^* = 10$ m at the injection in Run 3 improved pressure rise. β^* was 3 m in Run 2.
- A < 1 mm orbit drift at the RF loop-closing caused significant change in pressure rise.
- For proton run, pressure rise decreased as acceleration started.

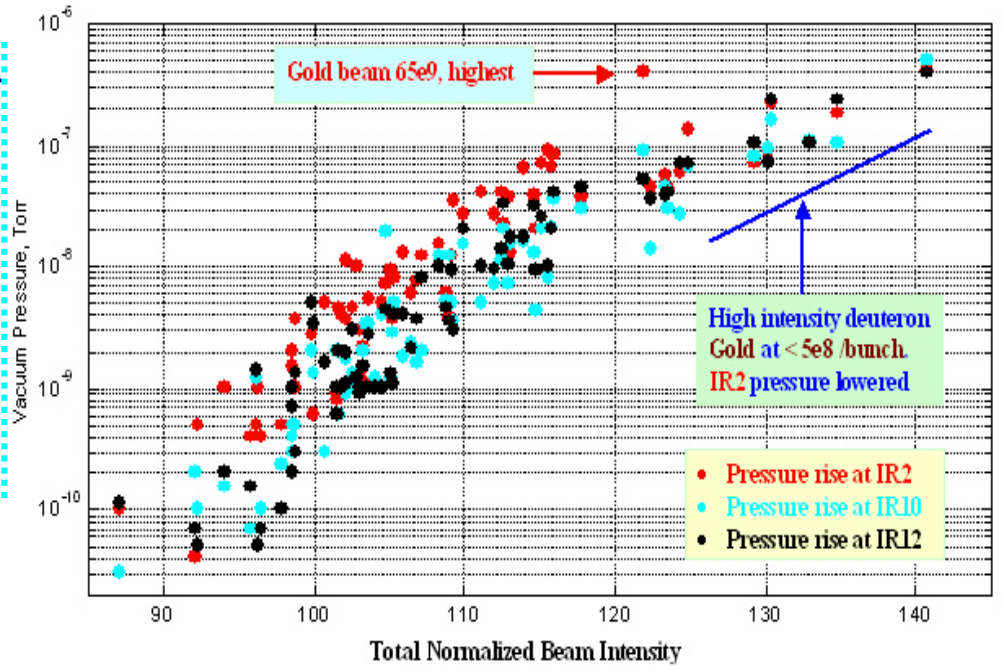


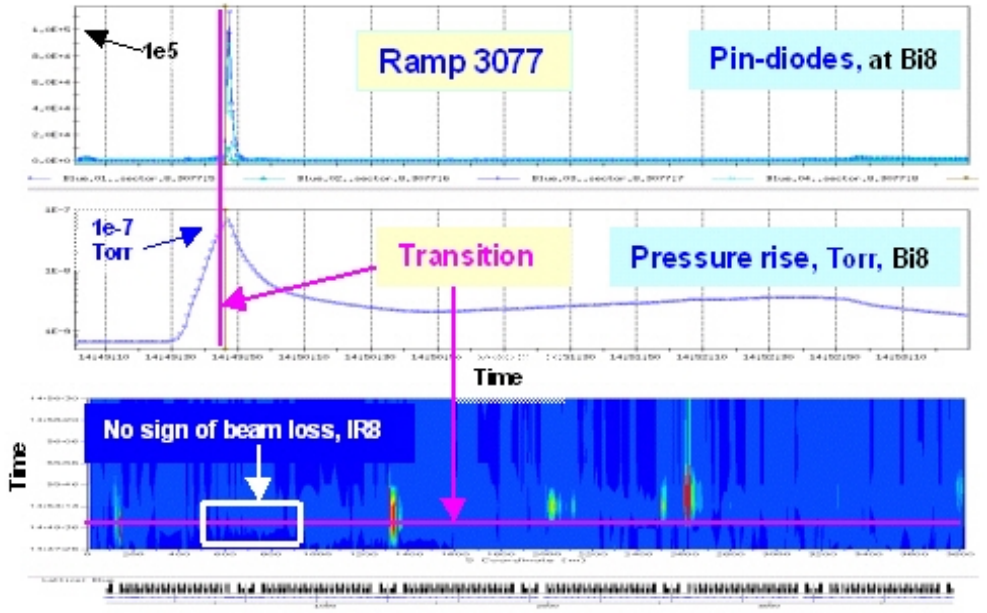




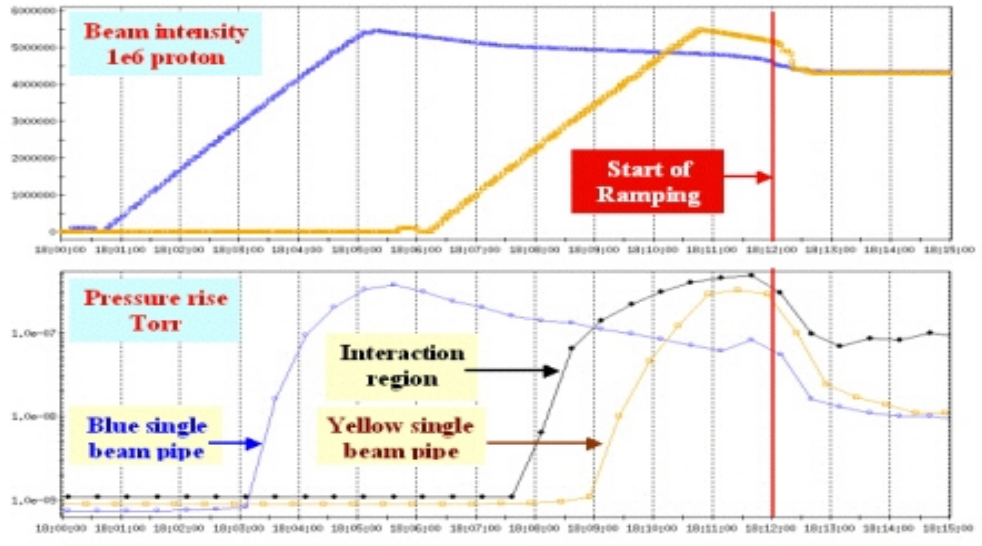
4. Transition pressure rise in gold and deuteron operations

- Transition pressure rise is quasi - exponentially proportional to total beam intensity.
- Not related to bunch spacing, 55 bunch and 110 bunch.
- Not related to beam loss.
- For same intensity, pressure rise at Q3 - Q4 is worse than at IR, similar to electron cloud induced pressure rise.
- Not related to ion species. Au's ionization cross section is much larger than deuteron's, so beam gas ionization is not a dominant factor?
- Pin-diode signals at Bi8 at the transition, no beam loss can be identified. Pressure rises in 2 orders of magnitude.

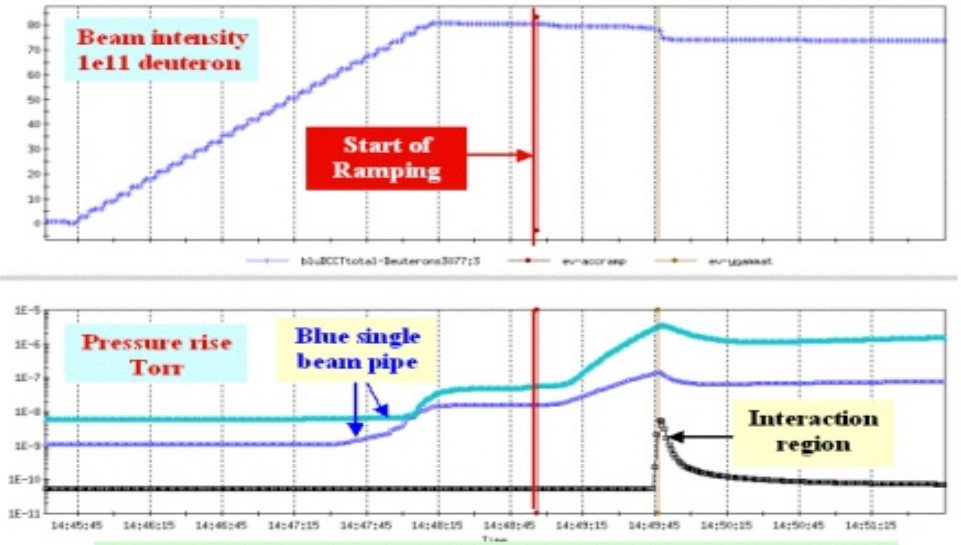




- In proton run, pressure rise decreased as ramp started. Both beam transverse size and momentum spread decreased as beam accelerated, which one is more important?
- Beam particles in bunch gap is probably not dominant, since otherwise pressure rise should happen at all similar chambers.
- In d-Au run, pressure rise increased as ramp started, and peaked at the transition.
- At the d-Au acceleration, beam transverse size decreased, but the beam momentum spread increased, and peaked at the transition.
- The beam momentum spread may produce halo at the quads, due to the nonlinearities.



Proton run: pressure rise decreases as ramp started



Au & d run: pressure rise increases as ramp started peaked to the transition

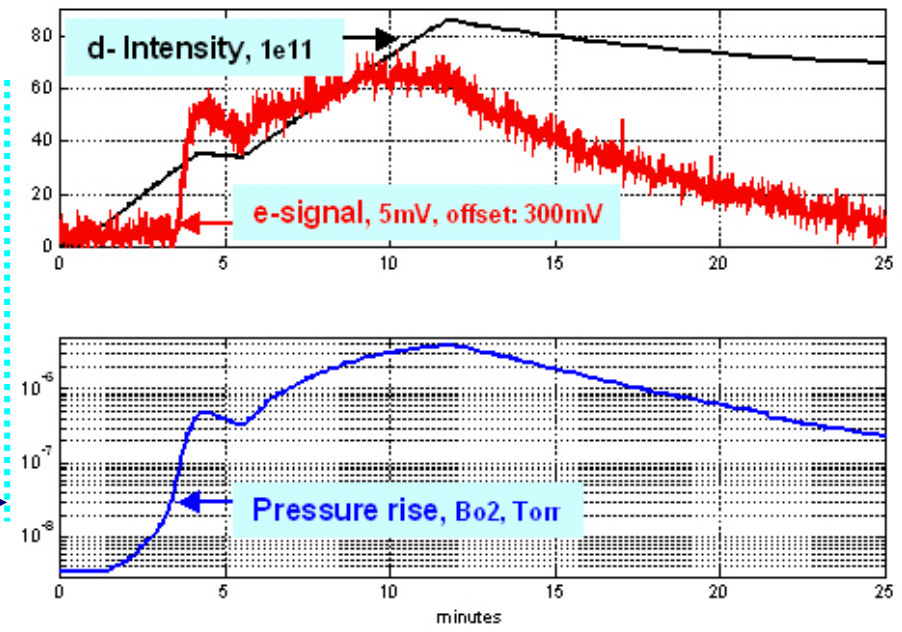
5. Effect of the beam halo scraping

1. RHIC electron cloud and pressure rise observed with up to 216 ns bunch spacing.	↔	1. Halo scraping produced ions may help secondary electrons to survive long bunch gap.
2. Pressure rise is localized, and locations may change.	↔	2. Halo scraping depends on the beam tuning and locations.
3. Single beam straight section's thresholds much lower than IR.	↔	3. Longer straight sections increase yield of halo scraping?
4. IR12 pressure rise much worse than IR4, chambers are same.	↔	4. Less interruption in pipe helps the beam scraping yield.
5. Beam steering may affects pressure rise.	↔	5. Beam steering affects halo scraping.
6. Gold beam pressure rise is much worse than proton beam.	↔	6. Gold beam scraping produces more ions. Ion production ~ q^3.
7. Pressure rise reduces at the beam acceleration in proton ramp.	↔	7. Smaller beam size and momentum spread reduces beam scraping?
8. Pressure rise increases at the gold and deuteron beam ramp, peaked at the transition.	↔	8. Gold beam momentum spread increases at the acceleration, and peaked at the transition.

6. Questions

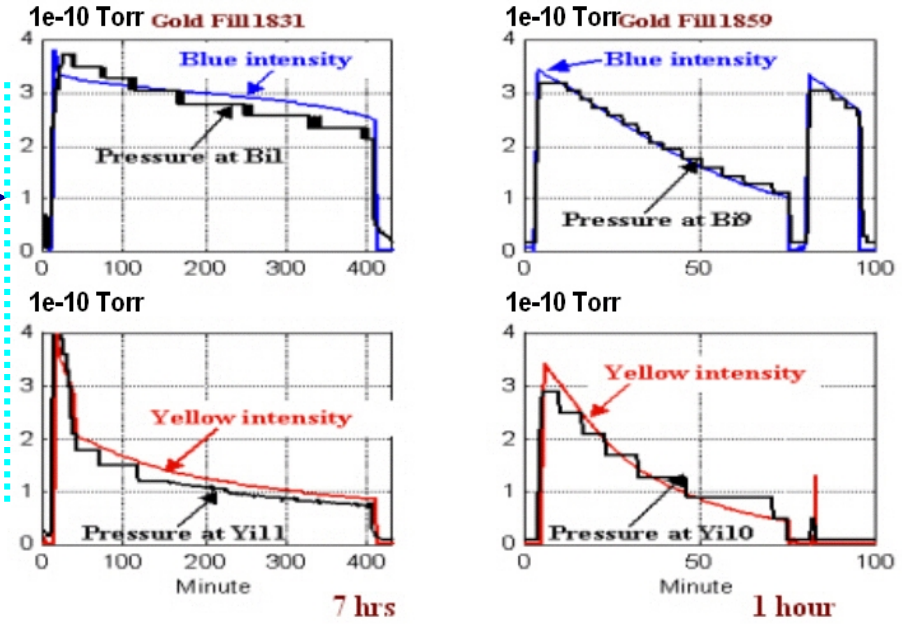
1. Electron cloud and pressure rise

- There is a close relation between injection pressure rise and e-signal for Au, d, and proton runs.
- Quantitative explanation is needed, by better electron detection and analysis.
- Pressure rise looks similar to e - signal, but it is in log scale.



2. Halo scraping and pressure rise

- Low pressure rise in 1e-10 Torr range is linearly proportional to beam intensity, rather than the beam loss, normal halo?
- Transition pressure rise is quasi - exponentially proportional to total beam intensity.
- Evidence so far did not agree with the electron cloud and ISR type ion desorption.

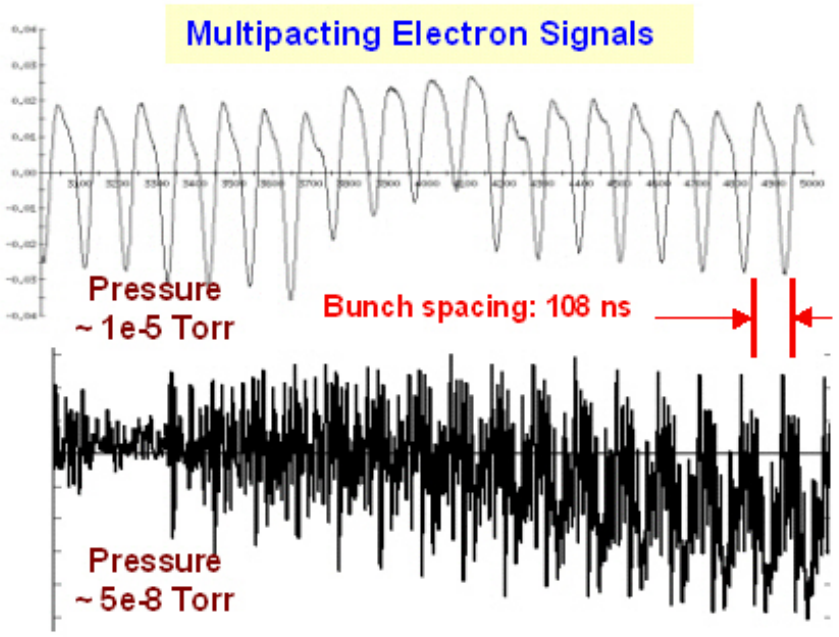


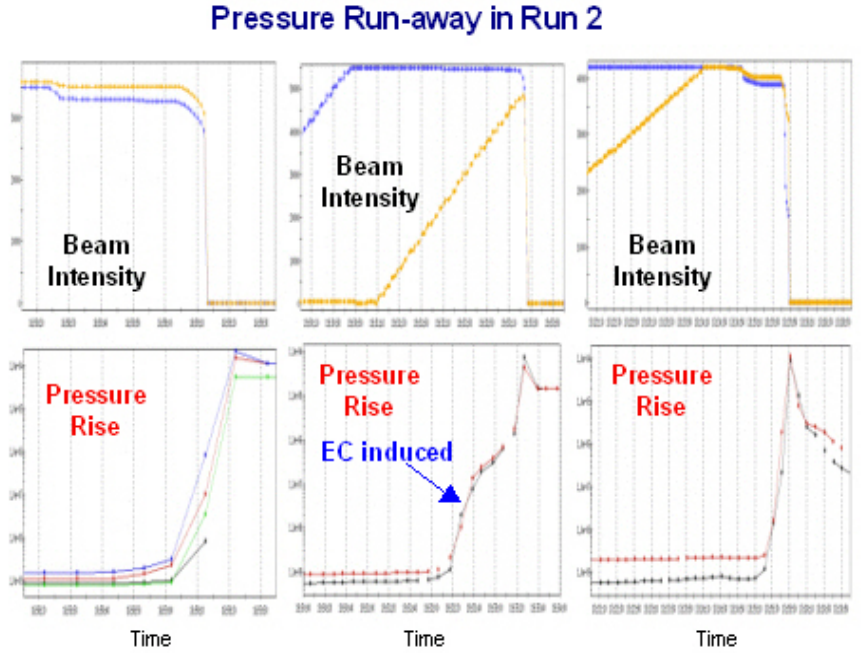
3. Pressure rise and electron signal

- Electron multipacting signals at high and low pressure rises are very different.
- Ion - electron plasma exists at high pressure. Electrons and ions respond differently at bunches' passing (dynamics).
- Beam gas desorption (ion), ion and electron desorption (electron, ion, neutral particle), ...
- Electrons' role is more important?

4. Run away type pressure rise

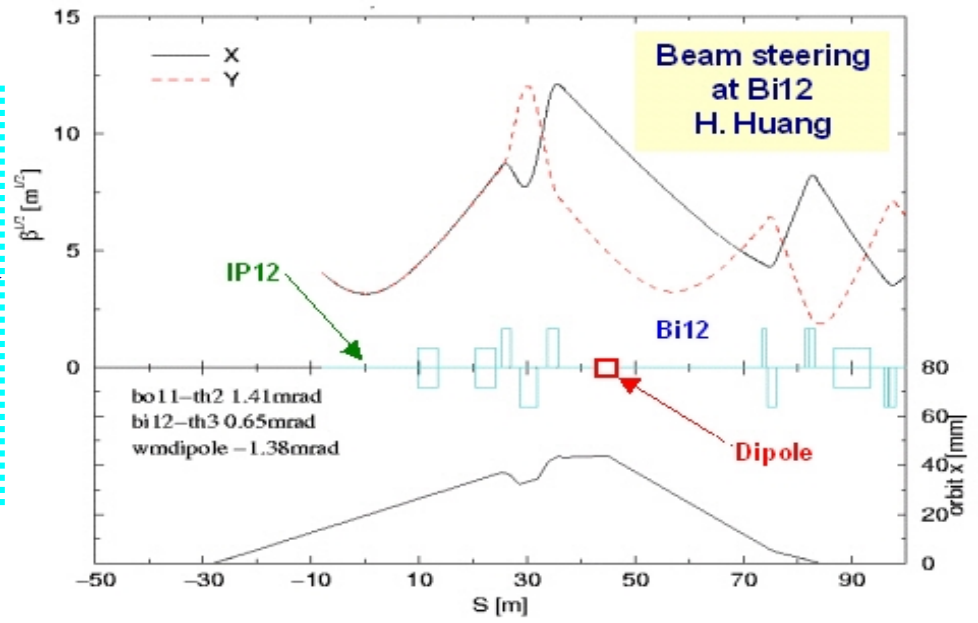
- Quite few pressure run away in Run 2 with gold beam, but all were accompanied with beam loss.
- It is possible that the beam loss created ions raised the electron cloud space charge limit.
- Beam loss may also create run-away type pressure rise?

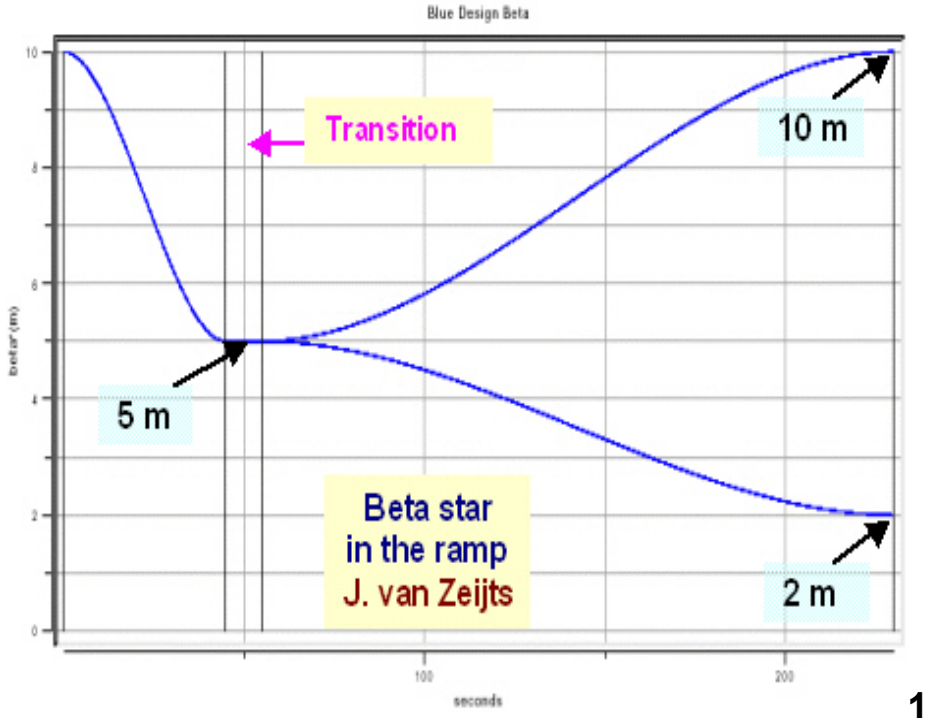




7. Study plans

1. **Beam scraping**
   - Beam scraping tested in Run 3. Loss spread in 300 meters.
   - Two steering dipoles at Bi12, and Yo10 (NEG pipe). Pin-diode at Bi12.
   - Ion desorption of high energy ion particles at glancing angle.
   - Compare steel and NEG walls.
2. **β* effect for transition pressure rise**
   - α1 and tune variation were main concerns to choose β* = 5 m at the transition.
   - In d-Au run, the transition beam loss was small, showing that there might be some room.
   - Transition β* = 8 m at the IR10, PHOBOS detector, for study?



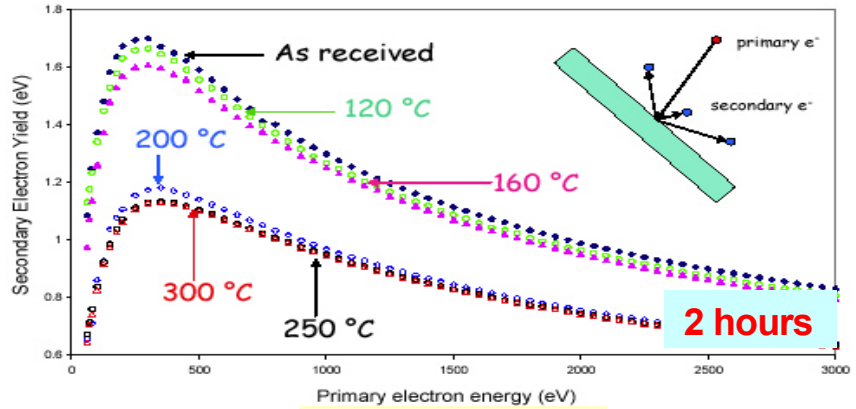


3. NEG pipes in RHIC

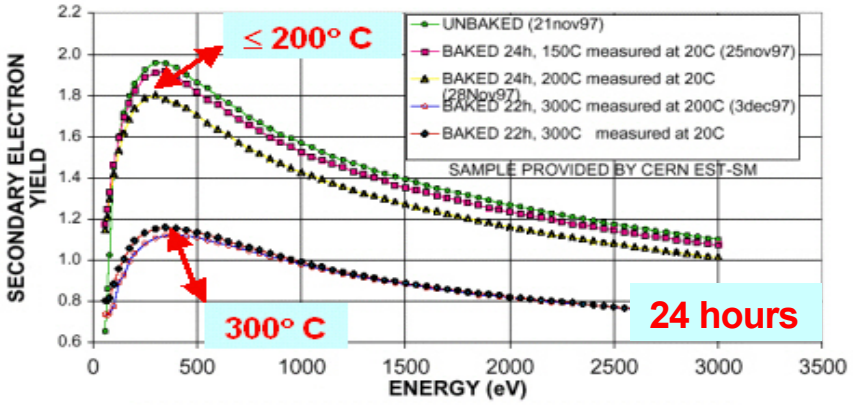
- 11 NEG coated pipes, each 5.2 m long, installed in RHIC.
- Main purpose is to verify its effectiveness for both EC and transition type pressure rise.
- Some confidence with SEY and electron desorption, not yet for Ion desorption.
- Activation conditions?

4. NEG pipes in Tandem

- Verify NEG pipes for RHIC.
- Ion desorption of NEG coated pipe, at glancing angle beam scraping, different activations, at saturation.
- Activate 200° C, 250° C, 300° C.
- Use saturated NEG pipe to overcome the complication of large pumping capability of NEG film.



P. Chiggiato, 2003



N. Hilleret, Two-Stream WKSP, 2001